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Lim et al.

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(54) **LIGHT-EMITTING DEVICE**

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**

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H01L 33/58	(2010.01)
H01L 33/22	(2010.01)
H01L 33/44	(2010.01)
H01L 33/20	(2010.01)

(52) **U.S. Cl.**

CPC ***H01L 33/58*** (2013.01); ***H01L 33/22*** (2013.01); ***H01L 33/44*** (2013.01); *H01L 33/20* (2013.01); *H01L 2224/48091* (2013.01); *H01L 2933/0083* (2013.01); *H01L 2933/0091* (2013.01)

(58) **Field of Classification Search**

CPC H01L 51/5262; H01L 51/5271

USPC 257/98; 438/29

See application file for complete search history.

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(57) **ABSTRACT**

A light-emitting device, a method of fabricating the light-emitting device, a light-emitting device package and a lighting system are provided. The light-emitting device may include a substrate **105**; a first conductivity type semiconductor layer **12** disposed on the substrate **105**; an active layer **114** disposed on the first conductivity type semiconductor layer **12**; a second conductivity type semiconductor layer **16** disposed on the active layer **114**; a first electrode **131** disposed on the first conductivity type semiconductor layer **112**; a second electrode **132** disposed on the second conductivity type semiconductor layer **116**; a first light extraction pattern P provided on a top surface of the substrate **105**; and a second light extraction pattern **150** provided on sides of the substrate **105**.

12 Claims, 12 Drawing Sheets

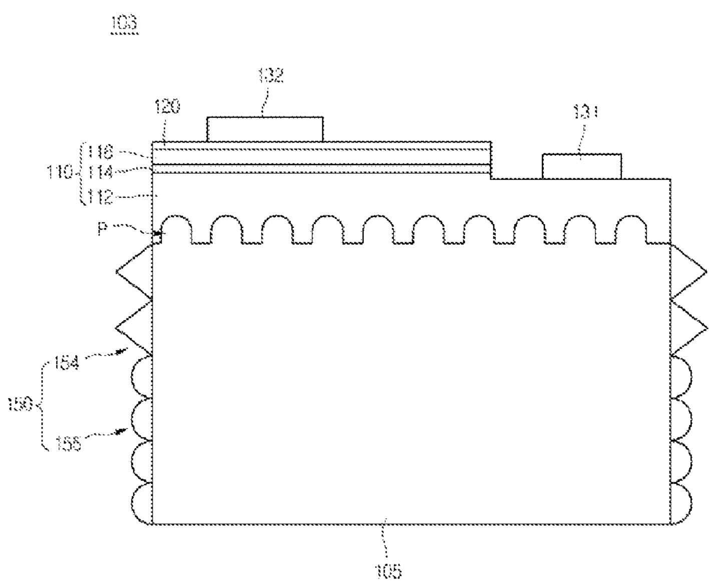


FIG. 1

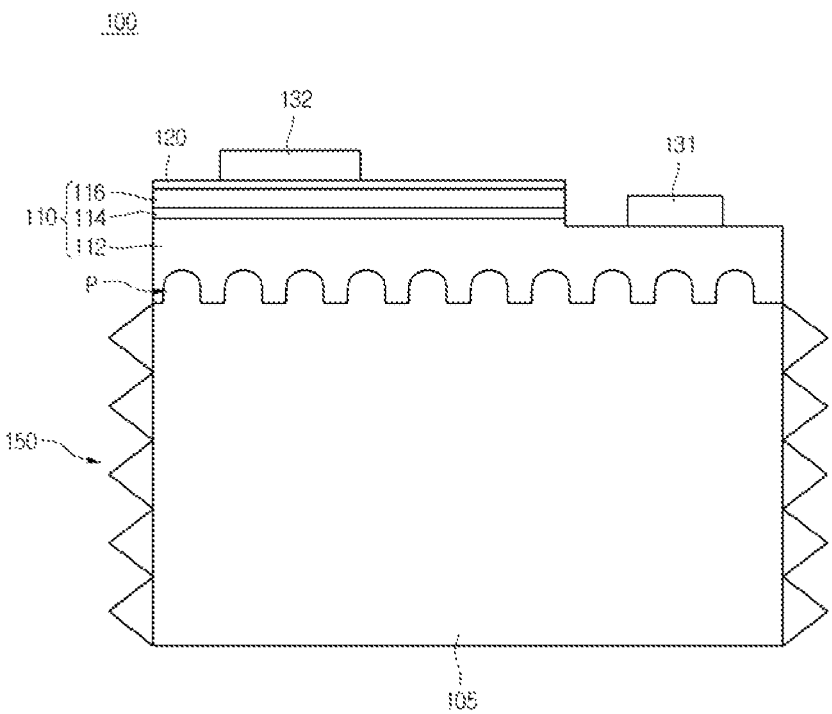


FIG. 2

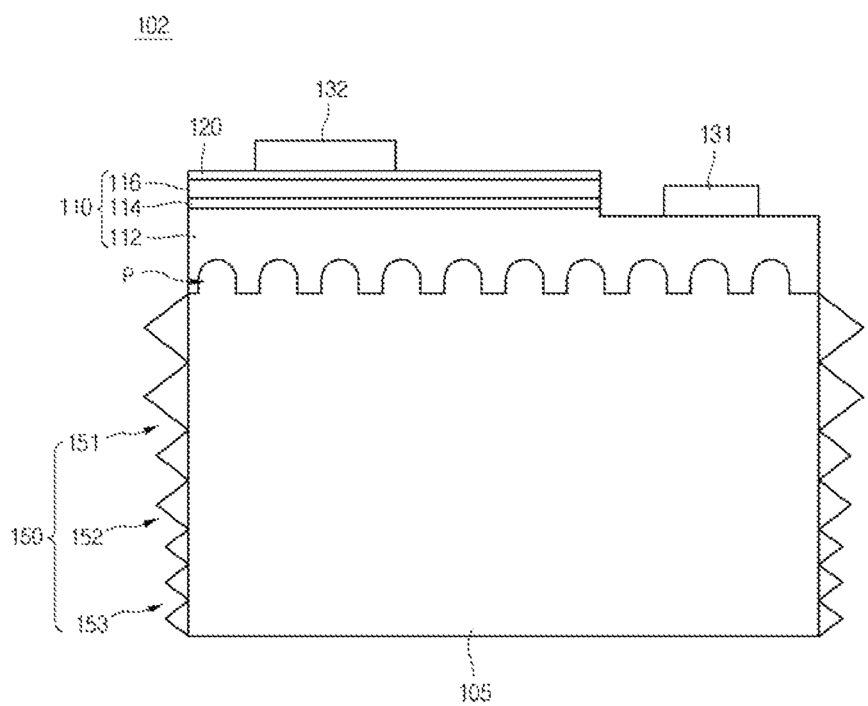


FIG. 3

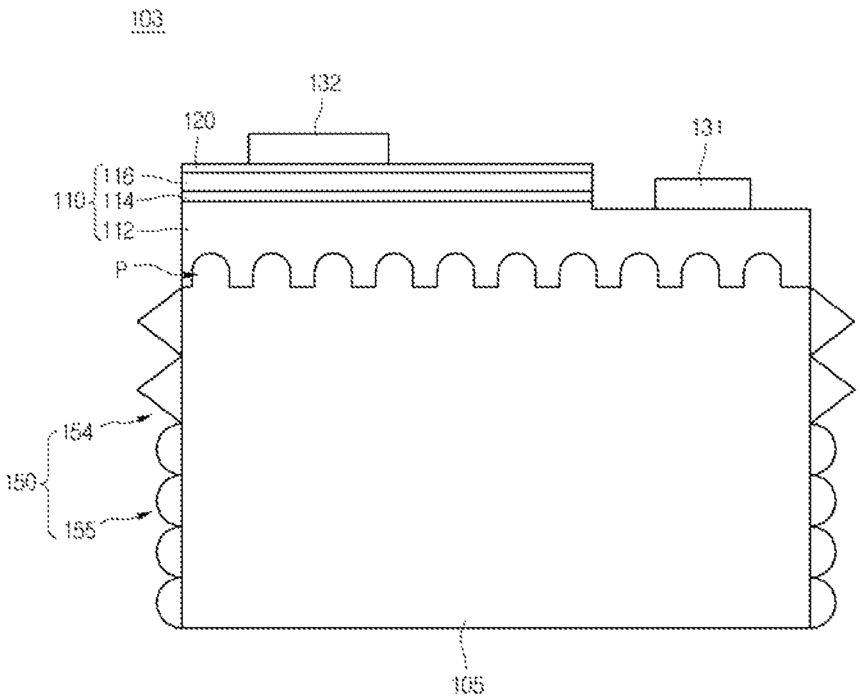


FIG. 4

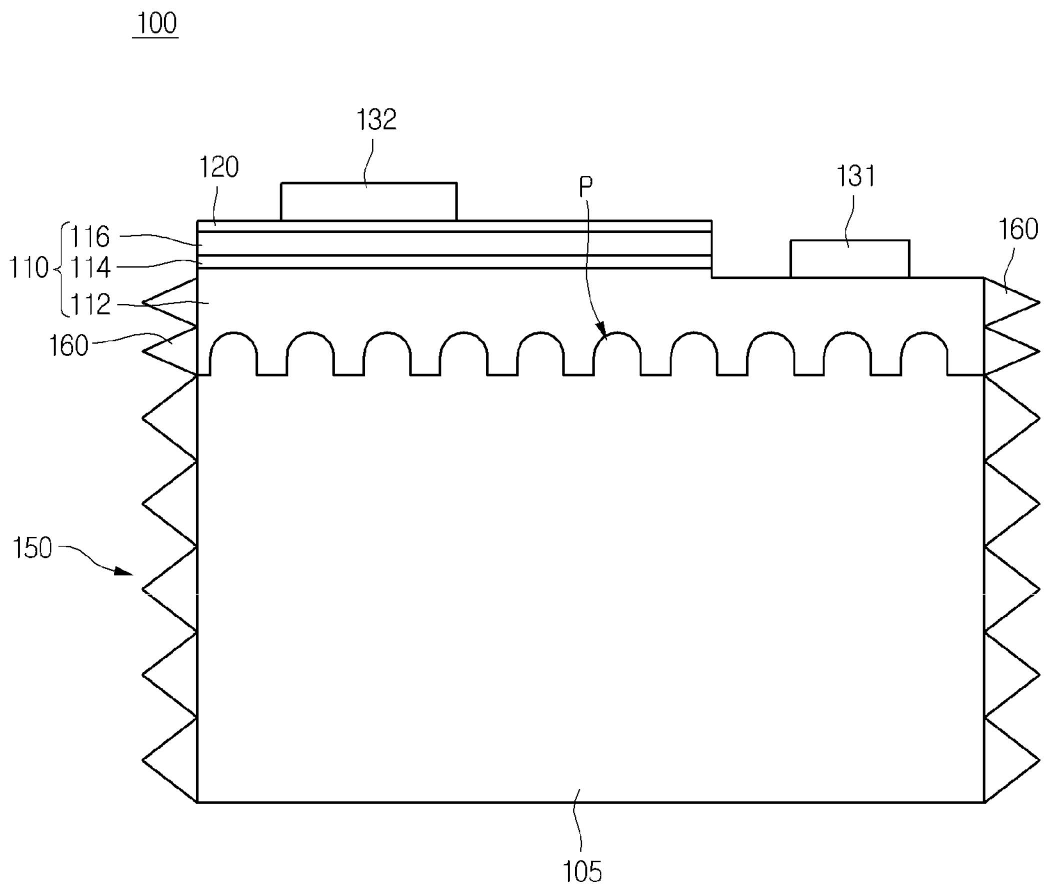


FIG. 5

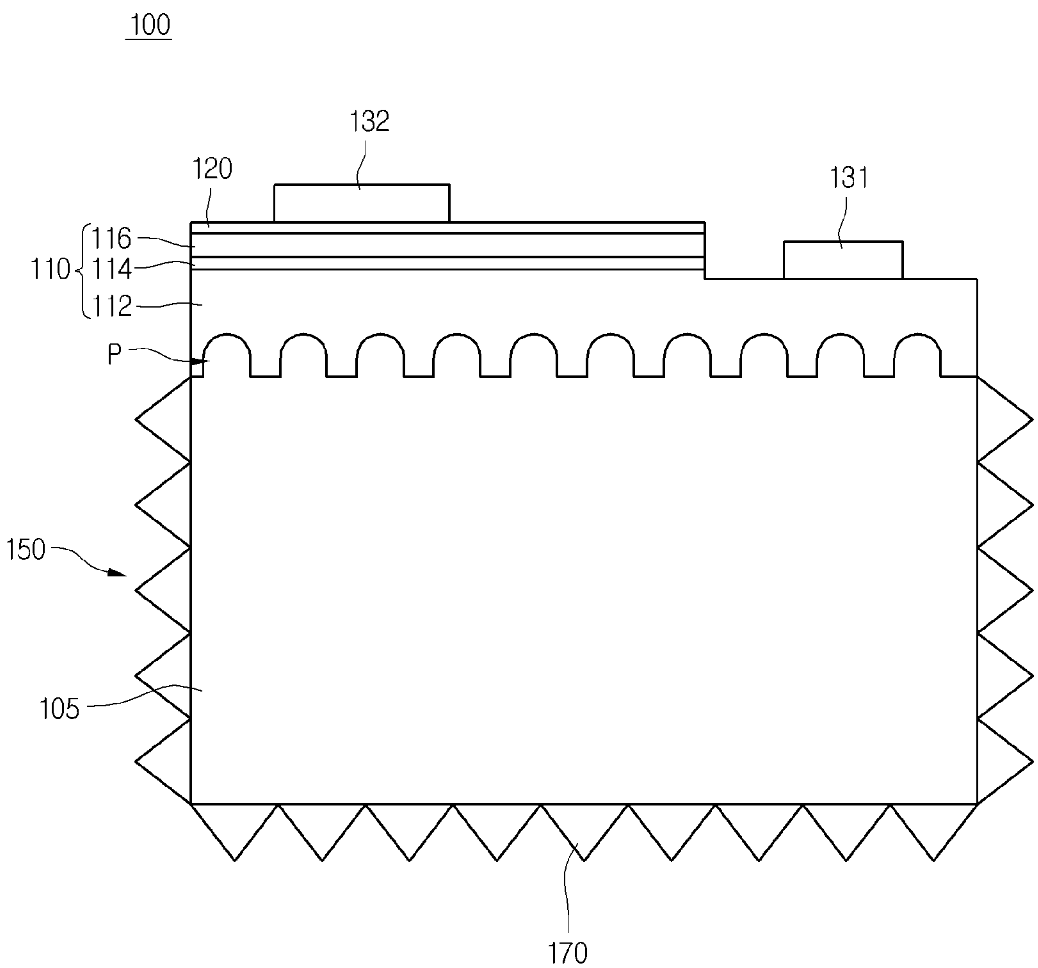


FIG. 6A

Prior Art

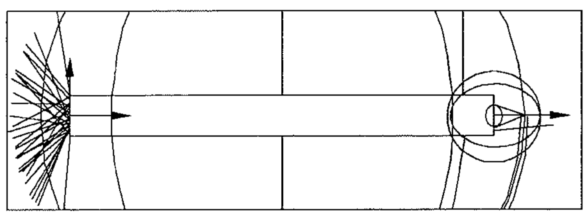


FIG. 6B

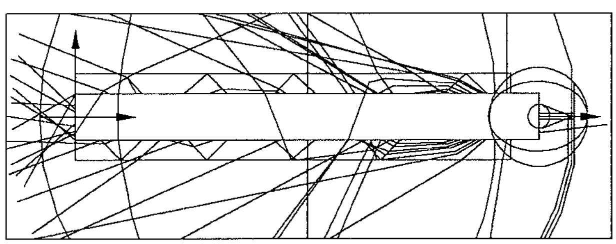


FIG. 7A

Prior Art

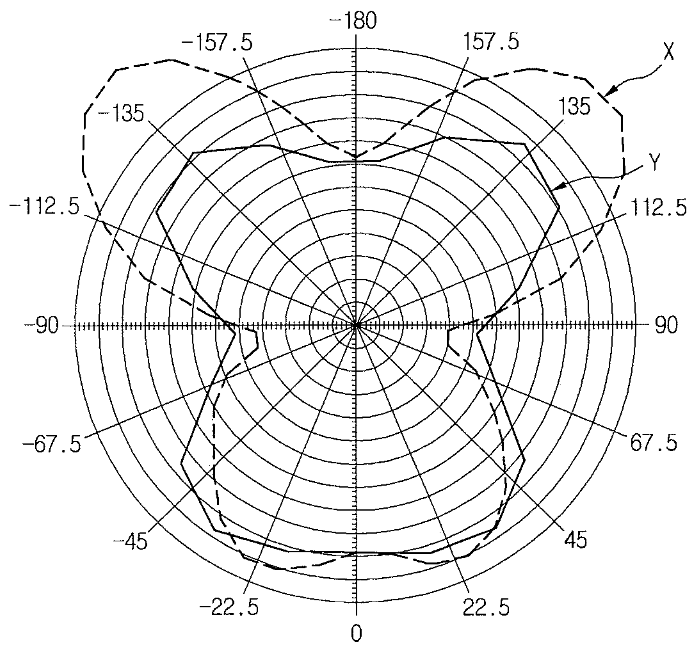


FIG.7B

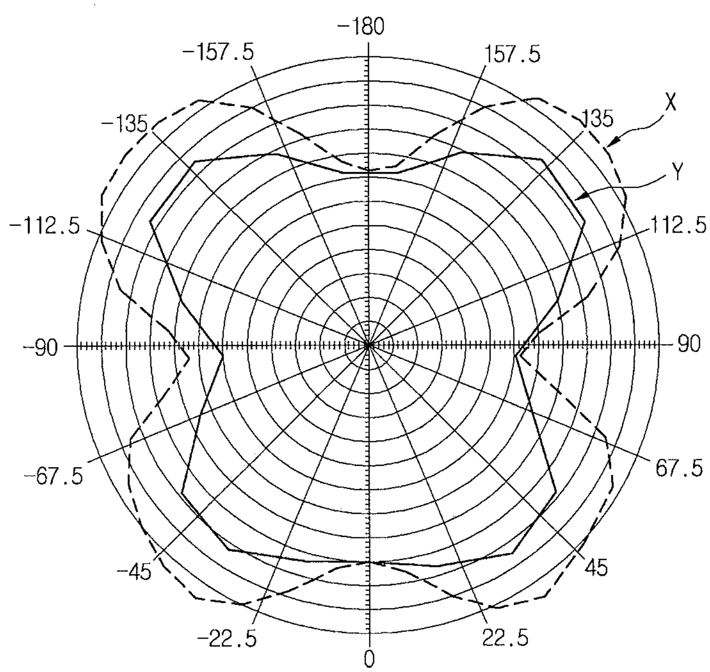


FIG.8A

Prior Art

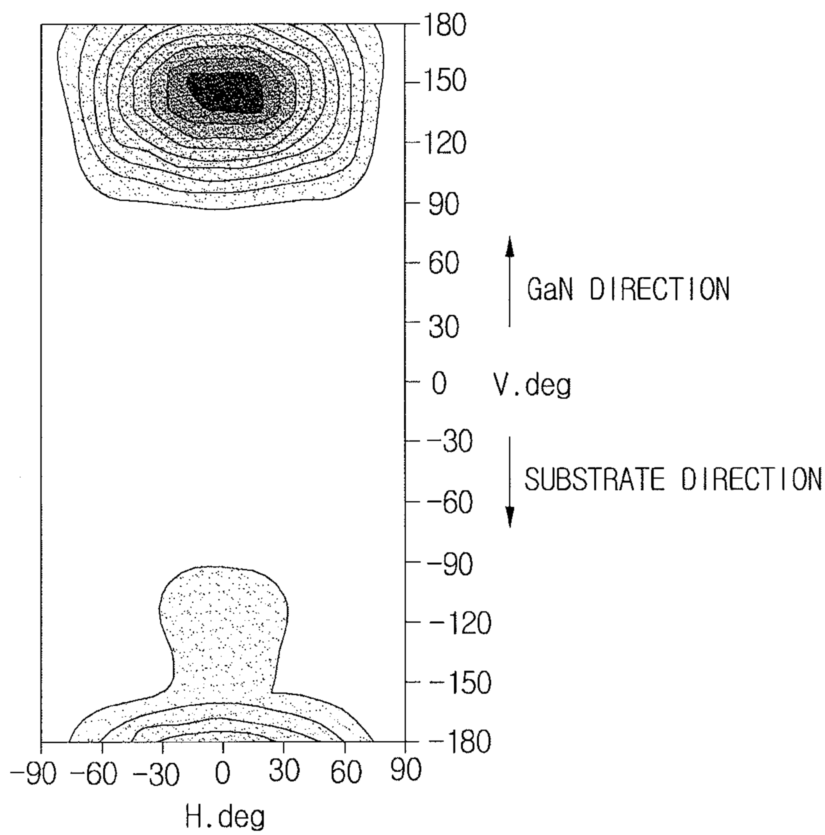
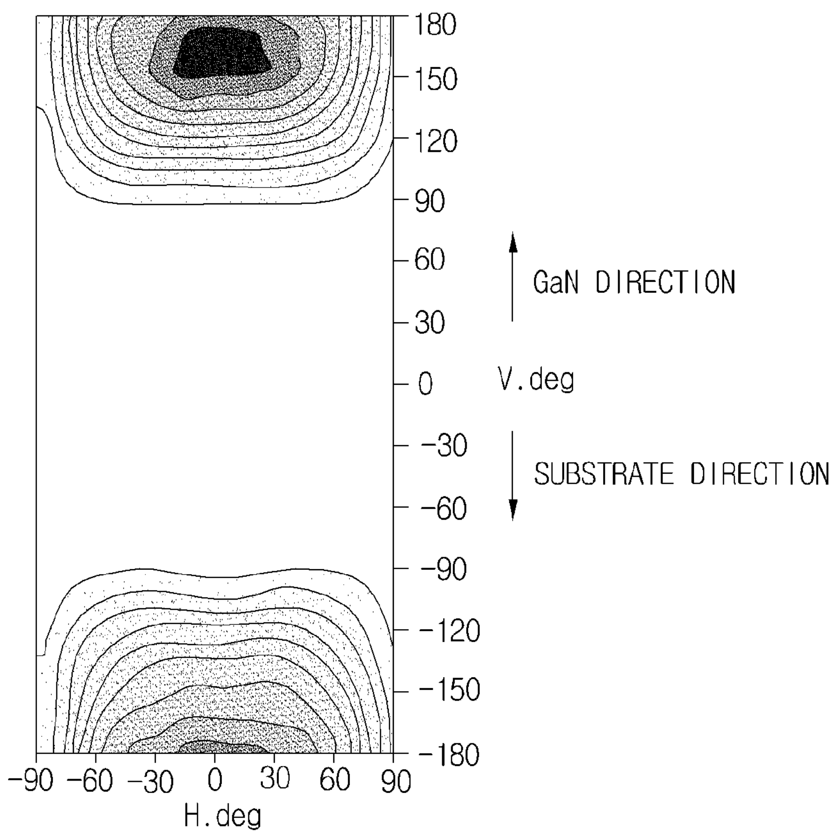


FIG.8B


180
150
120
90
60
30
0
-30
-60
-90
-120
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-180
GaN DIRECTION
V.deg
SUBSTRATE DIRECTION
-90 -60 -30 0 30 60 90
H.deg

FIG.9

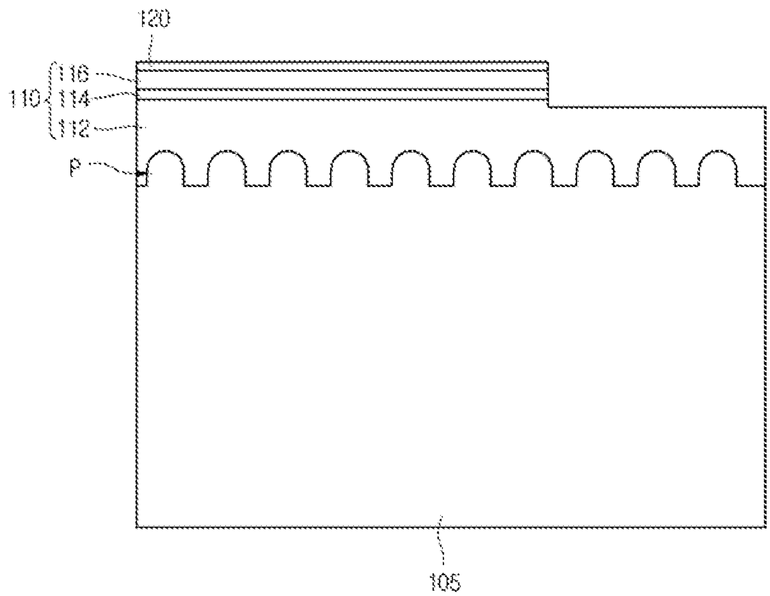


FIG.10

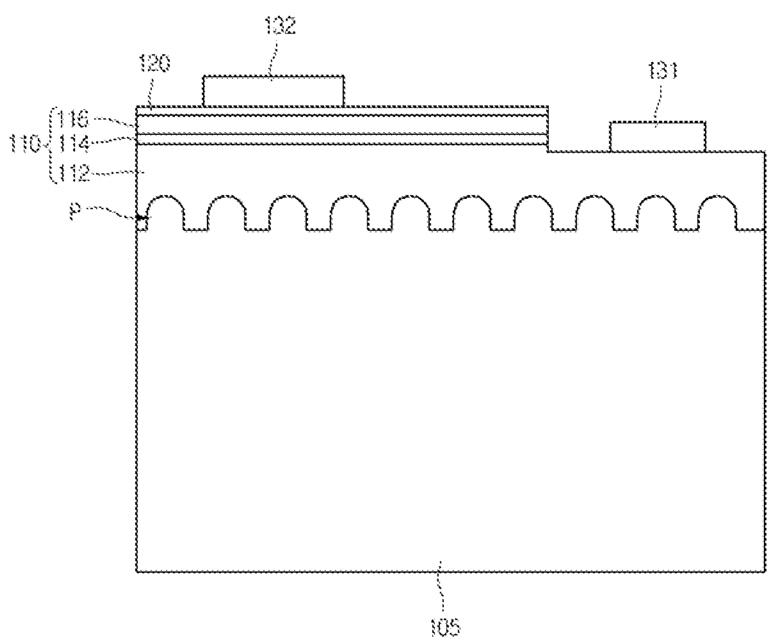


FIG. 11

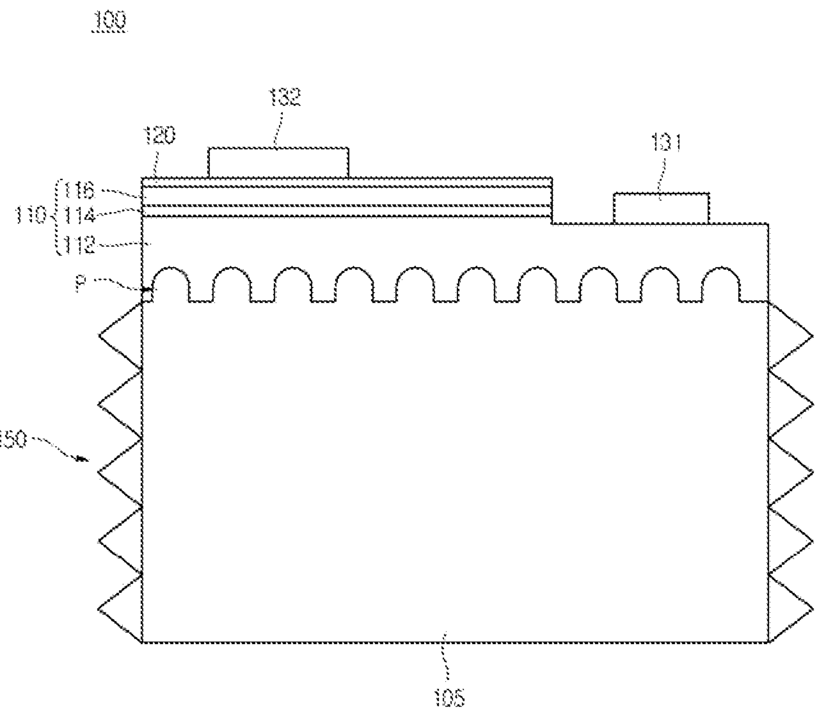
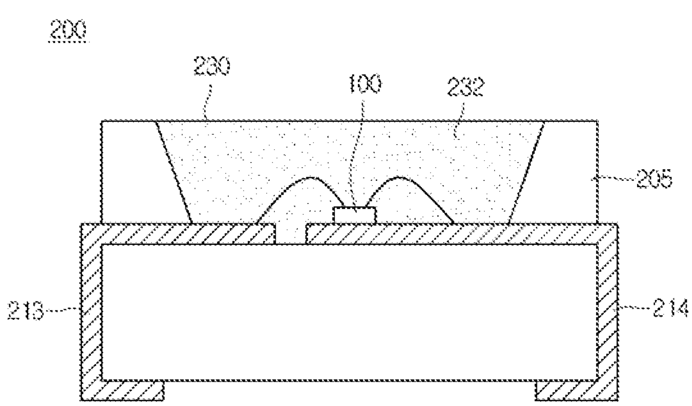

100
132
120
131
116
110
114
112
P
150
105

FIG. 12


200
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100
232
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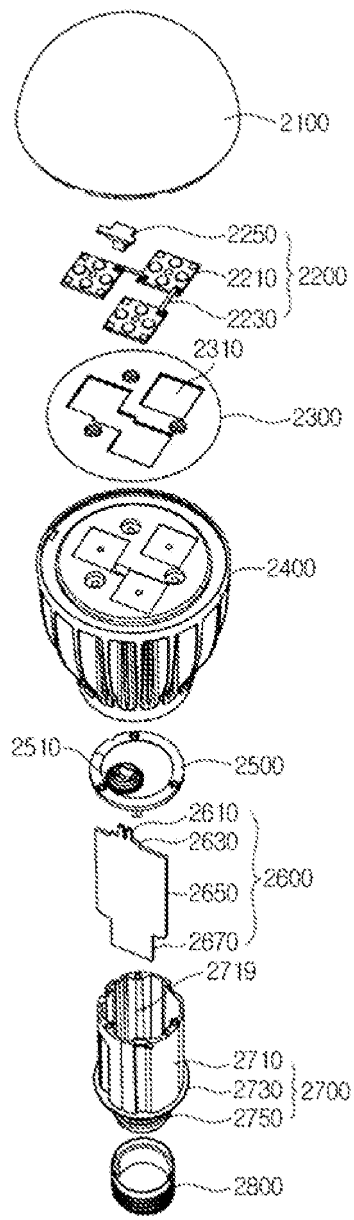
214

FIG. 13


2100
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2800

LIGHT-EMITTING DEVICE

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application claims priority under 35 U.S.C. §119 from Korean Patent Application No. 10-2011-0136834, filed on Dec. 16, 2011, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND

1. Field

Embodiments relate to a light-emitting device.

2. Description of the Related Art

Light-emitting devices are devices that convert electric energy into light energy and are capable of realizing various colors by adjusting the composition ratio of compound semiconductors.

When a forward voltage is applied, electrons from an n layer and holes from a p layer are combined to emit energy corresponding to an energy gap between a conduction band and a valence band. The energy is generally emitted in the form of heat or light. In light-emitting devices, in particular, the energy is emitted in the form of light.

Nitride semiconductors, for example, are attracting much attention for the fields of optical devices and high power electronic devices because of their high thermal stability and wide band gap energy. In particular, blue light-emitting devices, green light-emitting devices, and ultraviolet (UV) light-emitting devices that use nitride semiconductors have been commercialized and are widely used.

In related-art lateral light-emitting diodes (LEDs), a GaN epitaxial layer is grown on a patterned sapphire substrate, and p- and n-electrodes are formed with the use of a mesa structure.

The distribution of light in a related-art lateral LED shows that about 30% of light is emitted from the top of a GaN epitaxial layer and about 70% of the light is emitted from the bottom of a patterned sapphire substrate. More specifically, in a related-art lateral LED, most light is emitted from the bottom of the patterned sapphire substrate at a predetermined angle. That is, due to the total reflection caused by the difference between the refractive index of the patterned sapphire substrate and the refractive index of the air, most of the light beyond a predetermined critical angle cannot be emitted regardless of the presence of the patterned sapphire substrate.

SUMMARY

Embodiments provide a light-emitting device with improved light extraction efficiency, a method of fabricating the light-emitting device, a light-emitting device package and a lighting system.

In one embodiment, a light-emitting device includes: a substrate; a light-emitting structure disposed on the substrate; electrodes formed on the light-emitting structure; and a light extraction pattern provided on sides of the substrate, wherein the light extraction pattern includes a different material from the substrate.

In another embodiment, a light-emitting device includes: a substrate **105**; a first conductivity type semiconductor layer **12** disposed on the substrate **105**; an active layer **114** disposed on the first conductivity type semiconductor layer **12**; a second conductivity type semiconductor layer **16** disposed on the active layer **114**; a first electrode **131** disposed on the first conductivity type semiconductor layer **112**; a second electrode **132** disposed on the second conductivity type semiconductor layer **116**; a first light extraction pattern P provided on a top surface of the substrate **105**; and a second light extraction pattern **150** provided on sides of the substrate **105**.

A light-emitting device, a method of fabricating the light-emitting device, a light-emitting device package and a lighting system according to embodiments may improve light extraction efficiency.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and/or other aspects will be more apparent by describing certain exemplary embodiments with reference to the accompanying drawings, in which:

FIG. **1** is a cross-sectional view illustrating a light-emitting device according to a first embodiment;

FIG. **2** is a cross-sectional view illustrating a light-emitting device according to a second embodiment;

FIG. **3** is a cross-sectional view illustrating a light-emitting device according to a third embodiment;

FIG. **4** is a cross-sectional view illustrating a light-emitting device according to a fourth embodiment;

FIG. **5** is a cross-sectional view illustrating a light-emitting device according to a fifth embodiment;

FIG. **6**A is a diagram illustrating an example of the path of light in a related-art light-emitting device;

FIG. **6**B is a diagram illustrating an example of the path of light in a light-emitting device according to an embodiment;

FIG. **7**A is a diagram illustrating an example of the distribution of light in a related-art light-emitting device;

FIG. **7**B is a diagram illustrating an example of the distribution of light in a light-emitting device according to an embodiment;

FIG. **8**A is a diagram illustrating an example of the distribution of near-field light on the sides of the substrate of a related-art light-emitting device;

FIG. **8**B is a diagram illustrating an example of the distribution of near-field light on the sides of the substrate of a light-emitting device according to an embodiment;

FIGS. **9** to **11** are cross-sectional views illustrating a method of fabricating a light-emitting device, according to an embodiment;

FIG. **12** is a cross-sectional view illustrating a light-emitting device package according to an embodiment; and

FIG. **13** is an exploded perspective view of a lighting apparatus having a lighting device, according to an embodiment.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

Hereinafter, a light-emitting device, a method of fabricating the light-emitting device, a light-emitting device package and a lighting system according to embodiments will be described with reference to the accompanying drawings.

In the description of the embodiments, it will be understood that, when a layer (or film), a region, a pattern, or a structure is referred to as being "on" or "under" another substrate, another layer (or film), another region, another pad, or another pattern, it can be "directly" or "indirectly" over the other substrate, layer (or film), region, pad, or pattern, or one or more intervening layers may also be present. Such a position of the layer has been described with reference to the drawings. The thickness and size of each layer shown in the drawings may be exaggerated, omitted or schematically drawn for the purpose of convenience or clarity. In addition, the size of elements does not utterly reflect an actual size.

FIG. **1** is a cross-sectional view illustrating a light-emitting device **100** according to a first embodiment.

The light-emitting device **100** includes a substrate **105**, a light-emitting structure **110** disposed on the substrate **105**, electrodes formed on the light-emitting structure **110** and a second light extraction pattern **150** disposed on sides of the substrate **105**, and the second light extraction pattern **150** may include a different material from the substrate **105**.

The light-emitting structure **110** may include a first conductivity type semiconductor layer **112** disposed on the substrate **105**, an active layer **114** disposed on the first conductivity type semiconductor layer **112**, and a second conductivity type semiconductor layer **116** disposed on the active layer **114**. The electrodes may include a first electrode **131** disposed on a part of the first conductivity type semiconductor layer **112** that is exposed by partially removing the second conductivity type semiconductor layer **116** and the active layer **114**; and a second electrode **132** disposed on the second conductivity type semiconductor layer **116**.

The refractive index of the second light extraction pattern **150** may be greater than the refractive index of the substrate **105** so as to prevent total reflection and thus to improve light extraction efficiency. For example, the second light extraction pattern **150** may be formed of a silicone material, etc.

The second light extraction pattern **150** may be formed of a transmissive material, i.e., a material that transmits light there through, instead of reflecting light, so as to emit light.

The size of the second light extraction pattern **150** may be about 1/10 to about 1/5 of the thickness of the substrate **105** so as to effectively extract emitted light. For example, in response to the thickness of the substrate **105** being about 100 μm, the second light extraction pattern **150** may have, but is not limited to, a size of about 10 μm to about 20 μm.

In a case in which the second light extraction pattern **150** is arranged on the bottom surface of the substrate **105** in the form of parallel lines, the second light extraction pattern **150** may increase the lateral diffused reflection of light so as to improve lateral light extraction efficiency.

The second light extraction pattern **150** may be attached onto the sides of the substrate **105** or the light-emitting structure **110** by, for example, thermal treatment or the use of an adhesive material or pressure.

FIG. **2** is a cross-sectional view illustrating a light-emitting device **102** according to a second embodiment.

The second embodiment may employ the technical features of the first embodiment.

In the second embodiment, a second light extraction pattern **150** may include a first pattern **151**, a second pattern **152**, and a third pattern **153**, and the first pattern **151**, the second pattern **152**, and the third pattern **153** may have different sizes.

For example, the size of the first pattern **151** may be greater than the size of the second pattern **152**, and the first pattern **151** may be disposed closer than the second pattern **152** to an active layer **114**. In this example, since light extraction patterns of various sizes, periods, or heights are provided, it is possible to provide an appropriate light extraction structure for diffused reflected light and thus to improve light extraction efficiency.

The second pattern **152** and the third pattern **153** may be formed more densely than the first pattern **151** so that the optical output may be increased even in areas relatively distant from the active layer **114**.

According to the second embodiment, it is possible to improve light extraction efficiency by varying the shape of the second light extraction pattern **150**.

FIG. **3** is a cross-sectional view illustrating a light-emitting device **103** according to a third embodiment.

The third embodiment may employ the technical features of the first and second embodiments.

In the third embodiment, a second light extraction pattern **150** may include a fourth pattern **154** and a fifth pattern **155**, and the fourth pattern **154** and the fifth pattern **155** may have different shapes and may thus contribute to the improvement of light extraction efficiency.

For example, the fourth pattern **154** may have a triangular shape, and the fifth pattern **155** may have a semicircular shape. Accordingly, it is possible to provide an optimum optical extraction condition by providing a light extraction structure with patterns of various periods and heights.

FIG. **4** is a cross-sectional view illustrating a light-emitting device **104** according to a fourth embodiment.

The fourth embodiment may employ the technical features of the first, second, and third embodiments.

In the fourth embodiment, a light-emitting device **104** may also include a third light extraction pattern **160**, which is formed on the sides of a light-emitting structure **110**. For example, the third light extraction pattern **160** may be formed on the sides of a first conductivity type semiconductor layer **112** so as to improve light extraction efficiency.

The third light extraction pattern **160** may be formed of the same material as a second light extraction pattern **150**. For example, the third light extraction pattern **160** may include, but is not limited to, a silicone material.

The third light extraction pattern **160** may be formed of a different material from the second light extraction pattern **150**. For example, the third light extraction pattern **160** may be formed by etching the sides of the first conductivity type semiconductor layer **112**.

FIG. **5** is a cross-sectional view illustrating a light-emitting device **105** according to a fifth embodiment.

The fifth embodiment may employ the technical features of the first, second, third, fourth and fifth embodiments.

In the fifth embodiment, the light-emitting device **105** may also include a fourth light extraction pattern **170** formed on the bottom surface of a substrate **105**. Accordingly, in response to the light-emitting device **105** being mounted as a flip chip, the fourth light extraction pattern **170** may contribute to the improvement of light extraction efficiency at the bottom of the substrate **105** (i.e., the top of a light-emitting device package).

The fourth light extraction pattern **170** may be formed of a different material from the substrate **105**. For example, the fourth light extraction pattern **170** may be formed of the same material as a second light extraction pattern **150**.

The fourth light extraction pattern **170** may include the same material as the substrate **105**. For example, the fourth light extraction pattern **170** may be formed by etching the bottom surface of the substrate **105**.

The fourth light extraction pattern **170** may be vertically aligned with the first light extraction pattern P. Or the fourth light extraction pattern **170** may be vertically misaligned with the first light extraction pattern P.

Also, the fourth light extraction pattern **170** may include a different shape patterns comparing to the first light extraction pattern P. And, the fourth light extraction pattern **170** may include the same shape patterns comparing to the second light extraction pattern **150**.

FIG. **6**A is a diagram illustrating an example of the path of light in a related-art light-emitting device, and FIG. **6**B is a diagram illustrating an example of the path of light in a light-emitting device according to an embodiment.

Referring to FIGS. **6**A and **6**B, in a light-emitting device according to an embodiment, having a second light extraction pattern **150** disposed on the sides of a sapphire substrate **105** and formed of a different material from the sapphire substrate **105**, a considerable amount of light is extracted not only from the bottom of the sapphire substrate **105** but also from the sides of the sapphire substrate **105**, while in a related-art light-emitting device, most light is emitted from the bottom of a sapphire substrate.

FIG. **7**A is a diagram illustrating an example of the distribution of light in a related-art light-emitting device, and FIG. **7**B is a diagram illustrating an example of the distribution of light in a light-emitting device according to an embodiment. Referring to FIGS. **7**A and **7**B, X shows the distribution of light along a first axis of the light-emitting device according to an embodiment, and Y shows the distribution of light along a second axis, which is perpendicular to the first axis.

FIG. **8**A is a diagram illustrating an example of the distribution of near-field light on the sides of the substrate of a related-art light-emitting device, and FIG. **8**B is a diagram illustrating an example of the distribution of near-field light on the sides of the substrate of a light-emitting device according to an embodiment.

As illustrated in FIGS. **7**A, **7**B, **8**A, and **8**B, the amount of light emitted from the chip of the light-emitting device according to an embodiment is generally increased as compared to a related-art light emitting device, and a considerable amount of light is emitted even from the sides of the sapphire substrate of the light-emitting device according to an embodiment.

Simulation results show that the light extraction efficiencies before and after patterning are 58.5% and 67.8%, respectively. Accordingly, the light-emitting device according to an embodiment is expected to achieve an increase of about 16% in luminosity.

According to embodiments, it is possible to improve light extraction efficiency.

A method of fabricating a light-emitting device according to an embodiment will hereinafter be described with reference to FIGS. **9** to **11**.

Referring to FIG. **9**, a substrate **105** may be prepared. The substrate **105** may include a conductive substrate or an insulating substrate. For example, the substrate **105** may be at least one of sapphire (Al_2O_3), SiC, Si, GaAs, GaN, ZnO, GaP, InP, Ge, and Ga_20_3. Wet cleaning may be performed on the substrate **105** in order to remove impurities from the surface of the substrate **105**.

A first light extraction pattern P may be formed on the substrate **105**. The first light extraction pattern P may be formed of the same material as the substrate **105**. For example, the first light extraction pattern P may include, but is not limited to, a patterned sapphire substrate (PSS) formed on the substrate **105**.

Thereafter, a buffer layer (not shown) may be formed on the substrate **105**. The buffer layer may alleviate any misalignment between the material of the light-emitting structure **110** and the substrate **105**. The buffer layer may be formed of a group III-V compound semiconductor, for example, at least one of GaN, InN, AlN, InGaN, AlGaN, InAlGaN, and AlInN.

Thereafter, the light-emitting structure **110** may be formed on the buffer layer. The light-emitting structure **110** may include the first conductivity type semiconductor layer **112**, the active layer **114** and the second conductivity type semiconductor layer **116**.

The first conductivity type semiconductor layer **112** may be formed of a group III-V compound semiconductor doped with a first conductivity type dopant. In response to the first conductivity type semiconductor layer **112** being an N-type semiconductor layer, the first conductivity type dopant may be an N-type dopant, and may include Si, Ge, Sn, Se and Te.

The first conductivity type semiconductor layer **112** may include a semiconductor material of the composition $In_xAl_yGa_{1-x-y}N$ ($0 \le x \le 1$, $0 \le y \le 1$, $0 \le x+y \le 1$). For example, the first conductivity type semiconductor layer **112** may be formed of at least one of GaN, InN, AlN, InGaN, AlGaN, InAlGaN, AlInN, AlGaAs, InGaAs, AlInGaAs, GaP, AlGaP, InGaP, AlInGaP, and InP.

The first conductivity type semiconductor layer **112** may be formed by forming an N-type GaN layer with the use of chemical vapor deposition (CVD), molecular beam epitaxy (MBE), sputtering, hydride vapor phase epitaxy (HVPE), etc. The first conductivity type semiconductor layer **112** may also be formed by injecting a trimethyl gallium gas (TMGa), an ammonia gas (NH_3), a nitrogen gas (N_2) and a silane gas (SiH_4) containing n-type impurities such as silicon (Si) into a chamber.

A current spreading layer (not shown) may be formed on the first conductivity type semiconductor layer **112**. The current spreading layer may be, but is not limited to, an undoped GaN layer. The current spreading layer may be formed to, but is not limited to, a thickness of 50 nm to 200 nm.

An electron injection layer may be formed on the current spreading layer. The electron injection layer may be a first conductivity type gallium nitride layer. For example, for an effective electron injection, the electron injection layer may be doped with an n-type doping element at a concentration of 6.0×10^{18} atoms/cm^3 to 8.0×10^{18} atoms/cm^3.

A strain control layer (not shown) may be formed on the electron injection layer. For example, the strain control layer may be formed of $In_yAl_xGa_{(1-x-y)}N$ ($0 \le x \le 1$, $0 \le y \le 1$)/GaN. The strain control layer may effectively alleviate unusual stress that may be caused by any misalignment between the first conductivity type semiconductor layer **112** and the active layer **114**.

The strain control layer may be repeatedly deposited at least every six cycles. As a result, more electrons may gather at low energy levels of the active layer **114**, and thus, electrons and holes may become more likely to recombine. Accordingly, light-emitting efficiency may be improved.

Thereafter, the active layer **114** is formed on the strain control layer.

The active layer **114** may emit light corresponding to an amount of energy determined by the inherent energy band of the material of the active layer **114** upon electrons injected through the first conductivity type semiconductor layer **112** encountering holes injected through the second conductivity type semiconductor layer **116**.

The active layer **114** may be formed to have at least one of a single quantum well structure, a multi-quantum well (MQW) structure, a quantum-wire structure and a quantum dot structure. For example, the active layer **114** may have, but is not limited to, a MQW structure obtained by injecting TMGa, an ammonia gas (NH_3), a nitrogen gas (N_2), and a trimethyl indium gas (TMIn).

A well layer/barrier layer of the active layer **114** may have, but is not limited to, a pair structure obtained by using at least one of InGaN/GaN, InGaN/InGaN, GaN/AlGaN, InAlGaN/GaN, GaAs(InGaAs)/AlGaAs, and GaP(InGaP)/AlGaP. The well layer may be formed of a material having a smaller band gap than that of the barrier layer.

An electron blocking layer (not shown) is formed on the active layer **114**. The electron blocking layer may block electrons and may also serve as a MQW cladding layer for the active layer **114**, thereby improving light-emitting efficiency.

For example, the electron blocking layer may be formed of a $Al_xIn_yGa_{(1-x-y)}N$ ($0 \le x \le 1$, $0 \le y \le 1$)-based semiconductor. For example, the electron blocking layer may have a greater energy band gap than that of the active layer **114**, and may be formed to a thickness of about 100 Å to about 600 Å.

The electron blocking layer may be formed as, but is not limited to, an $Al_zGa_{(1-z)}N/GaN$ ($0 \le z \le 1$) superlattice.

The electron blocking layer may efficiently block overflown electrons from a p-type ion implantation, and may improve the efficiency of implantation of holes. For example, the electron blocking layer may efficiently block overflown electrons from an ion implantation performed with a Mg concentration of about 10^{18} to $10^{20}/cm^3$, and may improve the efficiency of implantation of holes.

The second conductivity type semiconductor layer **116** may include a group III-V compound semiconductor doped with a second conductivity type dopant, for example, a semiconductor material of the composition $In_xAl_yGa_{1-x-y}N$ ($0 \le x \le 1$, $0 \le y \le 1$, $0 \le x+y \le 1$). In response to the second conductivity type semiconductor layer **116** being a P-type semiconductor layer, the second conductivity type dopant may be a P-type dopant, and may include Mg, Zn, Ca, Sr, Ba, etc.

The second conductivity type semiconductor layer **116** may be formed as, but is not limited to, a P-type GaN layer obtained by injecting a TMGa, an ammonia gas (NH_3), a nitrogen gas (N_2) and bis(ethylcyclopentadienyl)magnesium containing p-type impurities such as Mg into a chamber.

The first conductivity type semiconductor layer **112** may be implemented as, but is not limited to an N-type semiconductor layer, and the second conductivity type semiconductor layer **116** may be implemented as, but is not limited to a P-type semiconductor layer. A semiconductor having the opposite polarity to a second conductivity type, for example, an N-type semiconductor layer (not shown), may be formed on the second conductivity type semiconductor layer **116**. Accordingly, the light-emitting structure **110** may be configured to have one of an N—P junction structure, a P—N junction structure, a N—P—N junction structure, and a P—N—P junction structure.

A transmissive electrode **120** may be formed on the second conductivity type semiconductor layer **116**. For example, for an efficient carrier injection, the transmissive electrode **120** may be formed by depositing a single metal or a metal alloy, a metal oxide, etc. so as to form a multiple layer. For example, the transmissive electrode **120** may be formed of, but is not limited to, at least one of indium tin oxide (ITO), indium zinc oxide (IZO), indium zinc tin oxide (IZTO), indium aluminum zinc oxide (IAZO), indium gallium zinc oxide (IGZO), indium gallium tin oxide (IGTO), aluminum zinc oxide (AZO), antimony tin oxide (ATO), gallium zinc oxide (GZO), IZO nitride (IZON), Al—Ga ZnO (AGZO), In—Ga ZnO (IGZO), ZnO, IrOx, RuOx, NiO, RuOx/ITO, Ni/IrOx/Au, Ni/IrOx/Au/ITO, Ag, Ni, Cr, Ti, Al, Rh, Pd, Ir, Ru, Mg, Zn, Pt, Au, and Hf.

Thereafter, the first conductivity type semiconductor layer **112** may be exposed by removing parts of the transmissive electrode **120**, the second conductivity type semiconductor layer **116**, and the active layer **114**.

Thereafter, referring to FIG. **10**, a first electrode **131** and a second electrode **132** may be formed on an exposed part of the first conductivity type semiconductor layer **112** and the transmissive electrode **120**, respectively.

Thereafter, referring to FIG. **11**, the second light extraction pattern **150** may be formed on sides of the substrate **105**. The formation of the second light extraction pattern **150** may be performed before the formation of the first electrode **131** and the second electrode **132**.

The second light extraction pattern **150** may be attached onto the sides of the substrate **105** or the sides of the light-emitting structure **110** by, for example, thermal treatment or the use of an adhesive material or pressure.

The second light extraction pattern **150** may include a different material from the substrate **105**.

The refractive index of the second light extraction pattern **150** may be greater than the refractive index of the substrate **105** so as to prevent total reflection and thus to improve light extraction efficiency. For example, the second light extraction pattern **150** may be formed of a silicone material, etc.

The second light extraction pattern **150** may be formed of a transmissive material, i.e., a material that transmits light therethrough, instead of reflecting light, so as to emit light.

The second light extraction pattern **150** may include a plurality of patterns. The patterns may be configured to have different sizes and shapes so as to uniformly extract light.

The size of the second light extraction pattern **150** may be about 1/10 to about 1/5 of the thickness of the substrate **105** so as to effectively extract emitted light. For example, in response to the thickness of the substrate **105** being about 100 μm, the second light extraction pattern **150** may have, but is not limited to, a size of about 10 μm to about 20 μm.

In a case in which the second light extraction pattern **150** is arranged on the bottom surface of the substrate **105** in the form of parallel lines, the second light extraction pattern **150** may increase the lateral diffused reflection of light so as to improve lateral light extraction efficiency.

In the second embodiment illustrated in FIG. **2**, the second light extraction pattern **150** may include the first pattern **151**, the second pattern **152**, and the third pattern **153**, and the first pattern **151**, the second pattern **152**, and the third pattern **153** may have different sizes. According to the second embodiment, it is possible to improve light extraction efficiency by varying the shape of the second light extraction pattern **150**.

In the third embodiment, the second light extraction pattern **150** may include the fourth pattern **154** and the fifth pattern **155**, and the fourth pattern **154** and the fifth pattern **155** may have different shapes and may thus contribute to the improvement of light extraction efficiency.

In the fourth embodiment, the light-emitting device **104** may also include the third light extraction pattern **160**, which is formed on the sides of the light-emitting structure **110**. For example, the third light extraction pattern **160** may be formed on the sides of the first conductivity type semiconductor layer **112** so as to improve light extraction efficiency.

The third light extraction pattern **160** may be formed of the same material as the second light extraction pattern **150**. For example, the third light extraction pattern **160** may include, but is not limited to, a silicone material.

The third light extraction pattern **160** may be formed of a different material from the second light extraction pattern **150**. For example, the third light extraction pattern **160** may be formed by etching the sides of the first conductivity type semiconductor layer **112**.

In the fifth embodiment, the light-emitting device **105** may also include the fourth light extraction pattern **170** formed on the bottom surface of the substrate **105**. Accordingly, in response to the light-emitting device **105** being mounted as a flip chip, the fourth light extraction pattern **170** may contribute to the improvement of light extraction efficiency at the bottom of the substrate **105** (i.e., the top of a light-emitting device package).

The fourth light extraction pattern **170** may be formed of a different material from the substrate **105**. For example, the fourth light extraction pattern **170** may be formed of the same material as the second light extraction pattern **150**.

The fourth light extraction pattern **170** may include the same material as the substrate **105**. For example, the fourth light extraction pattern **170** may be formed by etching the bottom surface of the substrate **105**.

In a related-art light-emitting device, most light is emitted from the bottom of a sapphire substrate. On the other hand, in a light-emitting device according to an embodiment, having the second light extraction pattern **150** formed on the sides of the substrate **105**, a considerable amount of light may also be extracted from the sides of the substrate **105**.

Also, the amount of light emitted from the chip of the light-emitting device according to an embodiment may increase, and a considerable amount of light may be emitted even from the sides of a sapphire substrate.

Also, simulation results show that the light extraction efficiencies of light-emitting device according to an embodiment achieves light extraction efficiencies of 58.5% and 67.8% before and after a patterning process, respectively, and is expected to achieve an increase of about 16% in luminosity.

The light-emitting device according to an embodiment can improve light extraction efficiency.

FIG. **12** is a diagram illustrating a light-emitting device package having a light-emitting device installed therein, according to an embodiment.

A light-emitting device package **200** includes a package body **205**, a third electrode layer **213** and a fourth electrode layer **214**, which are installed in the package body **205**, a light-emitting device **100**, which is installed in the package body **205** and is electrically connected to the third electrode layer **213** and the fourth electrode layer **214**, and a molding member **230**, which surrounds the light-emitting device **100**.

The package body **205** may be formed of a silicone material, a synthetic resin material or a metallic material. An inclined surface may be formed near the light-emitting device **100**.

The third electrode layer **213** and the fourth electrode layer **214** are electrically isolated from each other, and supply power to the light-emitting device **100**. The third electrode layer **213** and the fourth electrode layer **214** may improve light extraction efficiency by reflecting light emitted by the light-emitting device **100**. The third electrode layer **213** and the fourth electrode layer **214** may also discharge heat generated by the light-emitting device **100**.

A horizontal-type light-emitting device illustrated in FIGS. **1** to **5** may be used as the light-emitting device **100**, but the light-emitting device **100** is not limited to the horizontal-type light-emitting device.

The light-emitting device **100** may be installed on the package body **205** or on the third or fourth electrode layer **213** or **214**.

The light-emitting device **100** may be electrically connected to the third electrode layer **213** and/or the fourth electrode layer **214** by using at least one of wire, a flip chip method or a die bonding method. For example, the light-emitting device **100** may be connected to the third electrode layer **213** and the fourth electrode layer **214** by wire, as illustrated in FIG. **12**.

The molding member **230** may protect the light-emitting device **100** by surrounding the light-emitting device **100**. The molding member **230** may include a phosphor **232** and may thus change the wavelength of light emitted from the light-emitting device **100**.

In an embodiment, a plurality of light-emitting device packages may be arrayed on a substrate, and a light guide plate, a prism sheet, a diffusion sheet and a phosphor sheet, which are optical elements, may be disposed along the path of light emitted from the light-emitting device packages. In this embodiment, the light-emitting device packages, the substrate, and the optical elements may collectively serve as a backlight unit or a lighting unit. For example, a lighting system may include a backlight unit, a lighting unit, an instruction device, a lamp, a streetlamp, etc.

FIG. **13** is an exploded perspective view illustrating a lighting apparatus having a lighting device, according to an embodiment.

Referring to FIG. **13**, a lighting apparatus may include a cover **2100**, a light source module **2200**, a heat sink **2400**, a power source **2600**, an inner case **2700** and a socket **2800**. The lighting apparatus may also include at least one of a member **2300** and a holder **2500**. The light source module **2200** may include a light-emitting device or a light-emitting device package according to an embodiment.

For example, the cover **2100** may have a bulb shape or a hemispherical shape with a hollow inside and with part thereof open. The cover **2100** may be optically coupled to the light source module **2200**, and may also be coupled to the heat sink **2400**. The cover **2100** may be provided with a coupling unit for being coupled to the heat sink **2400**.

A milk-white paint containing may be coated on the inside of the cover **2100**. By using such milk-white material, it is possible to effectively scatter and diffuse light emitted from the light source module **220** and thus to emit the light.

The cover **2100** may be formed of glass, plastic, polypropylene (PP), polyethylene (PE), polycarbonate (PC), etc. PC, in particular, is a material with excellent light fastness, heat resistance and rigidity. The cover **2100** may be transparent so that the light source module **2200** may be seen therethrough. Alternatively, the cover **2100** may be opaque. The cover **2100** may be formed by blow molding.

The light source module **2200** may be disposed on one side of the heat sink **2400**. Accordingly, heat from the light source module **2200** may be transferred to the heat sink **2400**. The light source module **2200** may include a plurality of light-emitting devices **2210**, a plurality of connecting plates **2230** and a connector **2250**.

The member **2300** may be disposed at the top of the heat sink **2400**, and may include a plurality of guide grooves **2310** into which the light-emitting devices **2210** and the connector **2250** are respectively inserted. The guide grooves **2310** correspond to the substrates of the light-emitting devices **2210** and the connector **2250**.

The surface of the member **2300** may be coated with a white paint. The member **2300** reflects light reflected from the inside of the cover **2100** toward the light-emitting module **2200** back to the cover **2100**. Accordingly, the efficiency of the lighting apparatus may be improved.

For example, the member **2300** may be formed of an insulating material. The connecting plates **2230** of the light source module **2200** may include an electrically conductive material. Accordingly, the heat sink **2400** may be electrically connected to the connecting plates **2230**. The member **2300**, which is formed of an insulating material, may prevent the connecting plates **2230** and the heat sink **2400** from being short-circuited. The heat sink **2400** receives heat from the light source module **2200** and the power source **2600** and thus radiates heat.

The holder **2500** closes a receiving groove **2719** of an insulating portion **2710** of the inner case **2700**. As a result, the power source **2600**, which is disposed in the insulating portion **2710** of the inner case **2700**, is sealed. The holder **2500** has a guide a protrusion **2510**. The guide protrusion **2510** may be provided with a hole through which a protrusion **2610** of the power source **2600** penetrates.

The power source **2600** processes or converts an electrical signal provided by an external source and provides the processed or converted electrical signal to the light source module **2200**. The power source **2600** is disposed in the receiving groove **2719** of the inner case **2700**, and is sealed within the inner case **2700** by the holder **2500**.

The power source **2600** may include the protrusion **2610**, a guide **2630**, a base **2650**, and an extension **2670**.

The guide **2630** is formed to extend from one side of the base **2650** toward the outside of the power source **2600**. The guide **2630** may be inserted into the holder **2500**. Various parts may be disposed on one side of the base **2650**. The various parts may include, but are not limited to, a direct current (DC) converter, a driving chip for controlling the driving of the light source module **2200**, an electrostatic discharge (ESD) protection device for protecting the light source module **2200**, etc.

The extension **2670** protrudes from one side of the base **2650** toward the outside of the power source **2600**. The extension **2670** is inserted into the connecting portion **2750** of the inner case **2700**, and is provided with an electrical signal by an external source. For example, the width of the extension **2670** may be the same as or smaller than the width of the connecting portion **2750**. The extension **2670** may be electrically connected to the socket **2800** by wire.

The inner case **2700** may include a molding portion in addition to the power source **2600**. The molding portion is obtained by hardening a molding liquid, and allows the power source **2600** to be fixed inside the inner case **2700**.

A light-emitting device, a method of fabricating the light-emitting device, a light-emitting device package and a lighting system according to embodiments may improve light extraction efficiency.

Any reference in this specification to "one embodiment," "an embodiment," "example embodiment," etc., means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the invention. The appearances of such phrases in various places in the specification are not necessarily all referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with any embodiment, it is submitted that it is within the purview of one skilled in the art to effect such feature, structure, or characteristic in connection with other ones of the embodiments.

Although embodiments have been described with reference to a number of illustrative embodiments thereof, it should be understood that numerous other modifications and embodiments can be devised by those skilled in the art that will fall within the spirit and scope of the principles of this disclosure. More particularly, various variations and modifications are possible in the component parts and/or arrangements of the subject combination arrangement within the scope of the disclosure, the drawings and the appended claims. In addition to variations and modifications in the component parts and/or arrangements, alternative uses will also be apparent to those skilled in the art.

What is claimed is:

1. A light-emitting device comprising:

a substrate;

a first conductivity type semiconductor layer disposed on the substrate;

an active layer disposed on the first conductivity type semiconductor layer;

a second conductivity type semiconductor layer disposed on the active layer;

a first electrode disposed on the first conductivity type semiconductor layer;

a second electrode disposed on the second conductivity type semiconductor layer;

a first light extraction pattern provided on a top surface of the substrate; and

a second light extraction pattern provided on sides of the substrate,

wherein the second light extraction pattern comprises at least a fourth pattern and a fifth pattern, and the fourth pattern and the fifth pattern have different shapes to provide an optimum optical extraction condition by providing a light extraction structure with patterns of various periods and heights.

2. The light-emitting device of claim **1**, wherein the first light extraction pattern comprises the same material as the substrate, and the second light extraction pattern comprises a different material from the substrate, and

wherein the first light extraction pattern includes a hemispherical shape, and the fourth pattern and the first light extraction pattern have different shapes and heights.

3. The light-emitting device of claim **1**, wherein a refractive index of the second light extraction pattern is greater than a refractive index of the substrate.

4. The light-emitting device of claim **3**, wherein the second light extraction pattern comprises a silicone material.

5. The light-emitting device of claim **1**, wherein the second light extraction pattern is formed of a transmissive material.

6. The light-emitting device of claim **1**, wherein the second light extraction pattern comprises a plurality of patterns, and the plurality of patterns have different sizes and shapes.

7. The light-emitting device of claim **1**, wherein the fourth pattern is larger in size than the fifth pattern, and the fourth pattern is disposed closer than the fifth pattern to the active layer.

8. The light-emitting device of claim **1**, wherein the fourth pattern includes a triangular shape, and the fifth pattern includes a hemispherical shape.

9. The light-emitting device of claim **1**, wherein the size of the second light extraction pattern is about $1/10$ to about $1/5$ of the thickness of the substrate.

10. The light-emitting device of claim **1**, wherein the fifth pattern is formed more densely than the fourth pattern.

11. The light-emitting device of claim **1**, wherein the fourth pattern is vertically misaligned with the first light extraction pattern.

12. The light-emitting device of claim **1**, wherein the fifth pattern is vertically misaligned with the first light extraction pattern.

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